From Steelton to Mandalay

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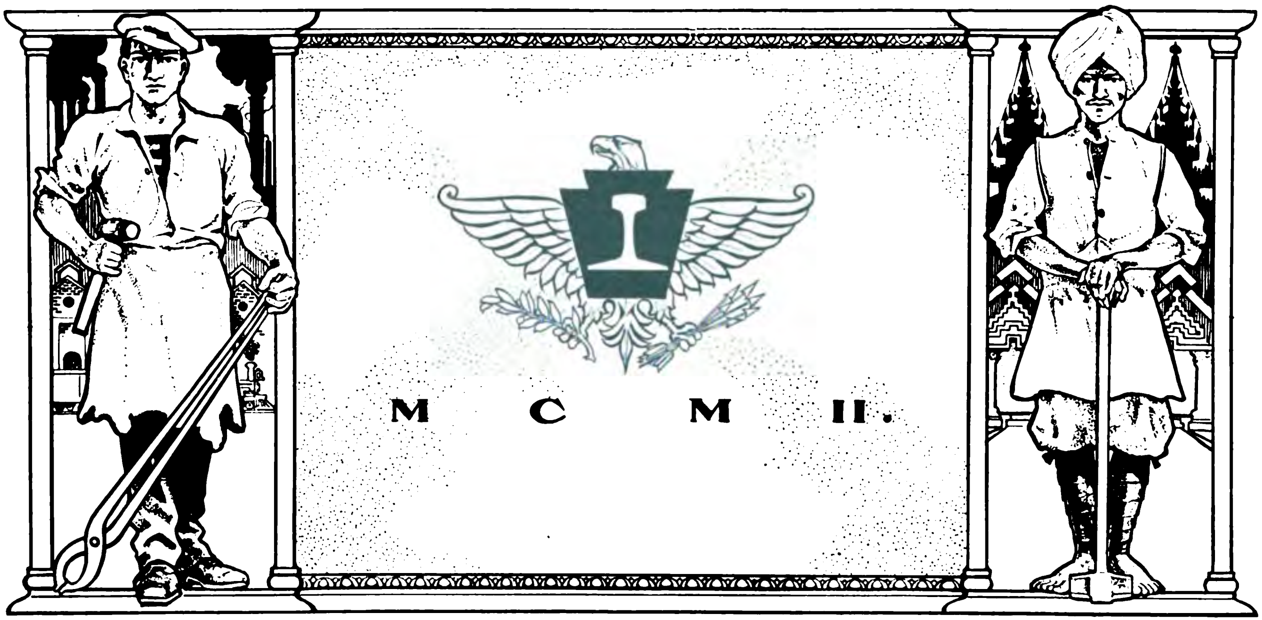
FROM STEELTON TO MANDALAY. A SHORT DESCRIPTION AND PICTORIAL HISTORY OF THE CONSTRUCTION OF THE GOKTEIK VIADUCT, BUILT BY THE PENNSYLVANIA STEEL COMPANY IN THEIR BRIDGE WORKS AT STEELTON PENNSYLVANIA, U. S. A.

From Steelton to Mandalay



THE PENNSYLVANIA STEEL COMPANY,
Steelton, Penn., U.S.A.

THE Gôkteik Viaduct is located in one of the Shan States of Upper Burma, 460 miles from Rangoon, the nearest seaport, and 80 miles east of Mandalay, on the road to Kunlon, which is on the frontier of China.

The structure, which was built for the Burma Railways Company, Limited, a railroad partly under the control of the Government of India, spans the Gôkteik Gorge, formed by the Chungzoune River, which disappears in a natural tunnel 500 feet below the viaduct foundations.

The contract was undertaken and executed under somewhat unusual circumstances, and the present pictorial history of the enterprise is published in response to requests from many quarters.

In explanation of the manner in which the operation was carried on, we append an account of the opening ceremonies in June, 1901, attended by the Lieutenant-Governor of Burma, Sir Frederic Fryer, K. C. S. I., also an article from the *World's Work*, bearing on some of the difficulties encountered during erection of the viaduct in Burma, and furthermore a general description of the work, reprinted from the *Engineering Record* of New York.

STATISTICS

[illegible]	[illegible]
2. [illegible]	[illegible]
3. [illegible]	[illegible]
4. [illegible]	[illegible]
5. [illegible]	1st February 1900
6. [illegible]	1st November 1900
7. [illegible]	[illegible]
8. [illegible]	[illegible] pounds
9. [illegible]	[illegible] pounds
[illegible]	[illegible] feet
[illegible]	[illegible] feet

12. Height [illegible] of rail above Chungzoune River	825 feet
13. Number of bridge erectors sent from America	35
14. Average number of skilled natives employed	350
15. Number of rivets driven in field by natives	200,000
16. Number of shop rivets	800,000
17. Number of separate pieces shipped from Steelton	232,868

Route from Steelton to Gökteik Gorge:

Steelton to New York	200 miles
New York to Gibraltar	3,300 miles
Gibraltar to Port Said	1,920 miles
Through the Suez Canal	87 miles
Suez to Aden	1,345 miles
Aden to Colombo	2,100 miles
Colombo to Rangoon	1,187 miles
Rangoon to Gökteik, by rail	460 miles
Total	10,599 miles

OPENING OF THE GOKTEIK VIADUCT

From "The Pioneer" of Allahabad

Maymyo, 4th June, 1901.

ABOUT 150 visitors from Maymyo, Mandalay, Rangoon and elsewhere in Burma, were invited by the Burma Railways Company to the opening ceremony at the Gôkteik Viaduct on the 1st of June. Among those present were the Lieutenant-Governor of Burma and Lady Fryer, the Honorable Hkun Saing, C. I. E., Sawbwa of Hsipaw, the Honorable Mr. D. Norton, C. S. I., and Mrs. and the Misses Norton, the Honorable Mr. Twomey and Mrs. Twomey, the Honorable Mr. J. Benton and Mrs. Benton, the Honorable Mr. H. M. S. Mathews, Colonel and Mrs. and the Misses Barrow, Mr. and Mrs. Corby Wilson, Colonel and Mrs. Trench, Mr. Gaitskell, the Rev. C. W. Hodder, Mr. and Mrs. A. E. Dyer, Mrs. Dyer, Mrs. and the Misses Simpson, Mrs. and Miss Tilly, Mrs. J. Algie, Miss Bashford, Mr. and Mrs. Wary, Mr. A. Weston, Mr. and Mrs. Moore, Mr. J. Dixon, Captain Henegan, Mr. Biggwither, Mr. and Mrs. Carnell, Captain Firth, Mr. and Mrs. Cardew, and Miss Cardew, Mr. E. G. Stanley, Mr. and Mrs. Deuchars, Mr. and Mrs. Johns, Mr. A. B. Skinner, Major H. Parkin, Mr. J. S. Brown, Captain Fryer, Captain Dunlop and others.

The party was taken from Maymyo to the Gôkteik Gorge by special train drawn by two new engines,

and on reaching the viaduct the Lieutenant-Governor drove in the last rivet, a silver one, on the first of the 120 foot spans, and declared the viaduct open for public traffic. This was about 10.30 a.m., and then the party re-entered the train and were taken across the viaduct and through the tunnels on the north side and up the loops for about three miles towards Hsipaw, and then returned to breakfast in a spacious shed facing the viaduct. An American flag had been specially brought out for this occasion by The Pennsylvania Steel Company's people at the end of 1899, when they came to start the work of erecting the viaduct, this and the English flag were the principal decorations behind the Lieutenant-Governor, and flowering orchids collected from the forests near by were hung around at the openings. After the breakfast, which was supplied by the Strand Hotel, Rangoon, Mr. Deuchars, the Engineer-in-Chief, got up and described the viaduct and the work generally. Sir Frederic Fryer then delivered a speech, and Mr. E. Johns, the Acting Agent, expressed his pleasure in welcoming the guests, and thanked the Lieutenant-Governor for the honour done the railway company in opening the viaduct, and for the great support given by him to the railway in all its undertakings. Soon after this the first ordinary passenger train was watched as it passed across the viaduct on its way to Hsipaw. The Sawbwa of Hsipaw and his son, Saw Hke, provided a Shan entertainment close by. During the afternoon some of the visitors went to the natural tunnel below the viaduct, where the stream flows at a level of 825 feet below the rails. The party started back about 5 p.m. for Maymyo, after a very successful and enjoyable day. The weather was brilliant after heavy rain in the early morning, and the Gôkteik Gorge with its bold scenery looked at its best. At the breakfast Mr. G. Deuchars, Engineer-in-Chief, Mandalay-Kunlon Railway, said:

Speech of Mr. G. Deuchars, Engineer-in-Chief.

Sir Frederic Fryer, Ladies and Gentlemen:

It has been suggested that I should tell you something about our work in crossing the Gókteik Gorge, and give you a brief description of the viaduct, the opening of which you have done us the honour of coming to witness. First about the viaduct. The general design was made by Sir A. M. Rendel & Co., the Consulting Engineers in London of the Burma Railways Company, and the erection was done, as you all know, by an American firm, The Pennsylvania Steel Company, **and a very fine job they have made. An immense amount of trouble was taken by them in designing the details, and the plans, consisting of more than 50 sheets, are a monument of careful and accurate work. All the pieces of the bridge were manufactured in America, and all fitted into their places with wonderful accuracy.** The contract for the work was let to the American company in April, 1899; the first consignment of material arrived in Rangoon in October of that year; the actual work of erection was started in December; and the viaduct was practically completed on November 1st, 1900, and was formally handed over to us in December. The viaduct is of rivetted steel throughout, and, light though it looks, contains no less than 4,308 gross tons of material. It is altogether 2,260 feet long and consists of 10 spans of 120 feet triangulated girders, and 7 spans of 60 feet plate girders. The supports on which the girders rest, and which constitute the more striking features of the viaduct, consist of steel towers. These towers are each made up of two trestles 24-½ feet wide across the top, and splaying outwards with a batter of 2-½ inches in the foot; the two trestles of the tower are spaced 40 feet apart, and are connected at the top by 40-foot plate girders, and the whole is securely braced in all directions. The rails are at a height of 2,135 feet above mean sea level, and are 825 feet

above the Chungzoune Stream, which flows through the natural tunnel below. The height of the rails above the ground at the highest pier is 325 feet. And now about the approaches, I mean the lines running down to the bridge on each side of the gorge. We have had a good deal more to do with them than we actually had with the construction of the bridge (I speak on behalf of Mr. Glascott, my very able Executive Engineer, and myself).

Mr. Bagley, who may be described as the father of the Mandalay-Kunlon Railway, as you are doubtless aware, discovered the natural bridge as far as the railway is concerned, and fixed the route for crossing the gorge, and it only remained for us to complete his work. It was a somewhat difficult matter to find a line which would give at once approximately the cheapest and most efficient approach to the bridge, and the line, as you see it, is the result of much consideration and discussion, and also, on the part of Mr. Glascott, of much hard work; he pretty well covered the hillsides with survey pegs before we got what we wanted. The south approach may be said to begin at a point about two miles north of Nawnghkio, at a level of 2,691 feet above the sea. From that point it descends to the bridge, which is at a level of 2,135 feet, on an almost continuous 1 in 40 gradient. The line after crossing the viaduct skirts the steep hillsides on the further side, involving two tunnels and some heavy cuttings, and then proceeds to turn and twist up the ascent by help of three semi-circular loops. Pinkaw (four miles from the viaduct) may be said to be the end of the north approach proper, but the line continues to ascend on a steep gradient for another nine miles, when it reaches a level of 3,256 feet above sea level, the highest point on the line between Maymyo and the Salween River.

A feature of the work in crossing the gorge is the temporary line, which is three miles long and zigzags down the side of the gorge. This temporary line enabled materials of all kinds to be delivered direct by train at the foot of the viaduct and greatly simplified the work of erection. It also

enabled us to cross rails and sleepers on a wire ropeway, so that plate-laying could be carried on the further side; two locomotives were even transported in pieces across this rope. This procedure enabled us to get the rails laid to a point about 35 miles ahead of the gorge by the time the viaduct was finished, and now admits of the line being opened to Hsipaw before the present rainy season, or six months earlier than would otherwise have been possible. It has also enabled us to get the large bridge over the Myitnge River, between Hsipaw and Lashio, spanned before the present rainy season, and has thus opened the possibility of the line being opened to Lashio in the beginning of 1902.

Speech of Sir Frederic Fryer, K. C. S. I., Lieutenant-Governor of Burma

Sir Frederic Fryer, K. C. S. I., Lieutenant-Governor of Burma, said:

Ladies and Gentlemen: We have met here to-day at the invitation of the Burma Railways Company in order to celebrate the opening of the Gôkteik Viaduct, a work which is the greatest of its kind in this province, and of which any country might be well proud. The Gôkteik Viaduct spans a formidable obstacle on the oldest and most direct route connecting Burma with Southwestern China, a route of which we have mention far back in ancient chronicles. It is, there is but little doubt, the same "gold and silver road" along which Marco Polo accompanied the Chinese invading armies on their march to Mandalay. In former times there was a very considerable traffic on it, but of late years the disturbed political condition of the countries through which it passes has led to much of the trade being diverted to other channels. It is hoped, however, that with the improved communications now being provided (and of which this Gôkteik Viaduct forms so important a feature) the trade will again return to this direct line connecting Mandalay with the Chinese frontier. No one who has seen

the Gôkteik Gorge and the fine structure which now spans it can fail to be impressed with the magnitude of the task which confronted the engineers when it was decided to take the railway across it. And indeed the preliminary determination of the best way to lay out the approaches and the fixing of the grades and the proper level for the viaduct were problems which involved a great deal of patient investigation and consideration. The first proposal was to use a rack on the Abt system for the line in the bridge approaches, with a rack inclined at 1 in 12½, similar to the railway up to Coonoor; this would have permitted of a comparatively short viaduct at the natural bridge, consisting of a 250-foot span on piers only 80 feet in height, with a few spans of 60 feet. Later on, when the construction of the line from Mandalay through the northern Shan States had been sanctioned, it was considered desirable to abandon the rack and to flatten the gradients to 1 in 25 for an adhesion track, similar to the 15-mile ghât length below Thondaung. A new survey was made on these lines, and it was found necessary to raise the viaduct by 70 feet and to increase its length to 1,350 feet. Still further investigation led to the belief that it would be possible to further improve the gradients in the approaches to the 1 in 40 standard, which prevails on the portion of the railway above Thondaung, and a new survey was made with a view to obtain 1 in 40 gradients. This was found possible, and the

1 in 40 grade was finally adopted; but the details of the approaches were modified more than once before they were finally fixed as we now see them. The viaduct itself is a very notable structure. There is indeed in existence one other viaduct on trestle towers which exceeds it by a few feet in height, but **for combination of height, length and weight of material, it occupies the first place among viaducts of its class.**

The general design of the bridge is, as you have heard, the work of Sir Alexander Rendel & Company, the Consulting Engineers to the Burma Railways Company. The bridge, however, was built by The Pennsylvania Steel Company, of Steelton, Pennsylvania, in the United States of America. Some comment has been made on the fact that the contract for the viaduct was given to an American company, but **our American cousins obtained the contract because they were able to submit the most favorable tender for its construction, both in point of cost and of time, and they have carried out the work with a celerity which excites our admiration.** They obtained the contract in April, 1899. The material for the viaduct began to arrive in October, 1899, and by December, 1900, the bridge was handed over to the Railways Company complete. Considering the size and character of the work, this may be considered a very good performance and **great credit is due to The Pennsylvania Steel Company and to their representatives here in Burma for the rapidity and the thoroughness of their work.** The names of the following officers of the Burma Railways Company who have been connected with this important work should be mentioned: Mr. Bagley, Chief Engineer, got out the original project for the rack approaches in 1892-93; in 1895-96 Mr. A. R. Lilley did the survey work for the 1 in 25 approaches. In May, 1898, a 1 in 40 line was submitted by Mr. Bagley, and then the Government of India proposed to raise the bridge and shorten the approaches, and a considerable amount of further survey work had to be undertaken, and every possible modification of

Mr. Bagley's latest plans was considered by Mr. Deuchars, the Chief Engineer, who succeeded Mr. Bagley in September, 1898. At length it was decided to adhere to the original height of the viaduct, but to re-align the whole of the approaches, and to curve the ends of the viaduct so as to reduce the cost of tunnels and earthwork. The result is the present line as it now is, and construction on it commenced in August, 1899. Mr. Glascott was in charge of the division, and he deserves great credit for the skill with which he worked out the details of the alignment both of the approaches and the bridge. He also had charge of the construction of the approaches, assisted by Mr. Bleeck, Assistant Engineer, and of the bridge itself, assisted by Mr. White, Executive Engineer. The principal credit is due, however, to the Engineer-in-Chief, Mr. Deuchars, who has been responsible for the conduct of the work, and who has had to guide his subordinates in all the intricate questions that have arisen regarding its construction. The construction of the approaches, involving very heavy work, has been carried out by Messrs. Glascott and Bleeck with skill and despatch. **As regards the viaduct itself, once the Railways Company had settled the location and the height, and fixed the pedestals on which the ends of the tower rest, the American company did the rest.** Thirty Americans were employed on the erection, and about 350 natives of India, chiefly rivetters.

The viaduct is now complete, and as a consequence of its completion and of the line, the railway is being opened for public traffic to Hsipaw to-day, and you will in a short time see from here the first passenger train pass over. The river Myitnge, between Hsipaw and Lashio, has just been spanned, one of the spans, viz. 200 feet, being the longest at present in Burma, and the line will, it is anticipated, be opened to Lashio early in 1902. Whether the railway will be carried beyond Lashio at present is a question that has not yet been decided; but, in my opinion, Lashio is not a very suitable terminus for caravans arriving from the Kunlon Ferry, as it is a small place with little trade, and water

there is scarce. A better terminus could, I believe, be found either in the Mongyaw or the Mongkyet valley, 30 or 50 miles from Lashio respectively, where the caravan road runs, and where there is an expectation of traffic. These valleys are fertile and only need population to be brought under cultivation. The province will, therefore, be much better off as regards railway communication when I hand over the administration than when I undertook it, and the Burma Railways Company certainly deserve our thanks for the increased facilities of railway communication which they have conferred on Burma since the Burma Railways were transferred them.

THE FOLLOWING ACCOUNT OF THE LOCAL CONDITIONS IN BURMA ARE CONDENSED FROM AN ARTICLE IN THE *World's Work* BY THE COMPANY'S RESIDENT ENGINEER:

Going up to Maymyo (only ten years ago a hornet's nest of dacoits, but now a thriving village, half European and half Burmese, soon to be the headquarters of the army of British Burma) we crisscrossed up the precipice on the east side of the Irrawady at a grade of one foot in twenty-five. In some places it was too steep for curves; switchback reversing stations came every other mile. First we climbed a mile forward, then we switched and climbed another backward—and so slowly upward. But the scenery was marvelous. Tumbled masses of purple teak-covered hills rolled away to the horizon, and the valleys were rocky canyons often a half mile deep, with icy streams at the bottom from slim white cataracts that poured down the canyon walls. At one point the train crawled along the face of the rock with a sheer drop away of fifteen hundred feet from the outside of the shelf. All the way up to the plain in the Shan Hills where Maymyo lies these spurs of the Himalayas outdid the Sierras in picturesqueness. On the plain itself, and indeed throughout the Shan States, though it has belonged to the Indian Empire for only fifteen years, the country has already been reduced to

systematic order; the former soldiers of Thibaw, the last of the Burmese kings, are now building better roads than those that are to be found in New England, and the reformed dacoit, as he cultivates his rice field and patches up his irrigation ditches, can see the steam road roller lumbering through jungle that he shared not long ago with elephants and tigers. The whole province, about as large as France, is the most prosperous in India. * * * * * *

Presently we arrived at the Gorge, with its stupendous natural bridge under which the Chungzoune runs, and were met by the Chief Engineer, Mr. Deuchars, who formed the plan of taking advantage of this formation and running the viaduct on its crest. By building across the natural bridge a viaduct three hundred and twenty feet high, it was possible for the railway to reach a natural shelf on the face of the cliff, up which it could climb on a steep grade to the top of the plateau some miles away, there to turn sharply to the northeast for the Kunlon Ferry.

Already the concrete piers for the trestle work had been built, and stretched in two apparently curving lines across the valley. Everything, in short, was ready, nothing remaining but to secure workmen, ship our material up from Rangoon, where it was arriving from New York by the American-Indian line, and begin operations. * * * * * *

This American invasion of Thibaw was signalized by a downpour of rain, tropic rain, that for steadiness and volume was phenomenal, the streams became torrents, the swamps became lakes, all work was stopped, the Mandalay-Kunlon was washed away in thirteen places, and all of Upper Burma sat down and waited for it to stop. In one place, as the road washed out, one of the new Baldwin locomotives, sent down the line in a brief lull, sank into the water-soaked embankment, and to the disgust of a Burmese farmer, slid into the adjoining rice field. To add to the confusion of the railway officials, who were waiting for the rain to stop to attack the thirteen washouts, our first

shipload of tools, material and erecting plant, which they had contracted to deliver to us at the Gorge, arrived at Rangoon, while the last twelve miles of track were unfinished.

Any great engineering project carried on ten thousand miles from home is bound to be full of difficulties, since all kinds of unforeseen accidents are likely to occur. At Gôkteik we had no sooner emerged from the rains than we were confronted with the problem of handling, sorting and storing material at the starting point of the viaduct in a cramped, inconvenient spot on the steep slope of a hill. In America a few carloads of material can be shipped as they are needed, but out there a second steamer load, comprising a full third of our material, was upon us before the first load had been properly stored and just as we were establishing our plant and beginning actual work in the field. The storage yard at the bridge head became a scene of mad activity. As the material came in from Mandalay, our big steam derricks whipped it out of the little, metre-gauge freight cars, and swung it over to the smaller derricks for final disposition, and coolies swarmed about with smaller pieces. The work went on with such speed that the native engine drivers and train hands could not shift empties in time to keep clear of the rush. So when too many of them accumulated, we picked them up with the fifteen-ton steam derrick, and set them down on the bank, where the drivers of the switching locomotives would discover them, fifty feet below the level of the track, piled up like empty dry goods boxes. * * * * * *

The method of erection is plainly shown in the photographs. The great traveler was first constructed directly upon the railway track on the embankment at the south end of the bridge, then, as soon as it was in working shape, the material for the first tower was passed out through it in proper order, lowered and bolted into position, in readiness for the native rivetters, then as soon as the tower had been pretty well rivetted, the big girders for the intervening space between the newly

constructed tower and the abutment on the bank were swung out; the longitudinal stringers and the cross floor beams followed; ties and rails were laid for the trains with material, and tracks were laid upon the girders for the traveler to run on. When everything had been completed, tackles were made fast to the traveler and to the forward end of the girders, lines were carried to the winding engine and the big 100-ton machine moved slowly forward to the edge of the newly finished structure; there it was bolted down in readiness for the next tower. To see it move ahead like a colossal drawbridge hundreds of feet in the air until the overhanging beams seemed on the point of toppling the whole mass over into the gorge was a sight that the natives could never look on with equanimity.

In all this work with the traveler the American workmen proved so efficient as compared with the natives that, roughly speaking, one American must be taken to equal at least four natives. Divided into castes and subdivided into trades, the natives were able to do but one kind of work; though in an American rivet gang there are but three men, all capable of doing any part of the work, the Indian natives are obliged to have in their gangs a hammer man, a snapman, a dolly holder, a man to heat the rivets and one to pump the bellows. The bellows men may not heat the rivets, the rivet heater may not swing a hammer, the hammer man may not hold a dolly bar, and when the gang are obliged to move they have to wait for the *khallassies*, or riggers, to rig their stagings. When the painting began on the viaduct, we found the painters, too, quite useless without the *khallassies.* Good workers at their trades they were, however, all of them, the rivetters from *Oudh* and the *Punjaub*, used to bridge work, and the *khallassies*, sailors mostly from coasting vessels or P. & O. steamers.

Usually, on Indian bridge-work, the British engineers put a thousand or two thousand of these natives under one or two Europeans, for they are docile as sheep, and have the same respect for their European overseers that sheep have for a collie; but we introduced the innovation of having

white men work. On the traveler, on the material as it went up, on the topmost points of the rising towers to connect the new pieces as the crane swung them up, the Americans and a few British and German sailors we had picked up, with one North Carolina negro who spoke *Hindustani*, worked hard, to the measureless surprise and admiration of the coolies, so that as soon as the construction of the viaduct got well under way, operations went on with tremendous rapidity, some of the two hundred foot towers, much like New York skyscrapers, going up in three or four days. When one thinks of the slow progress of an office building, rising gradually week by week, the speed of these Steelton workmen with their train of coolies may be comprehended. One whole month, however, was spent on the great double, three hundred and twenty foot tower directly on the natural bridge at the lowest point of its hollowed back. From 7 to 12 and from 1:45 to 6 the men worked. Over the traveler was spread an awning for protection from the sun, but as much of the work was done in the open, the men, dressed as thinly as possible in *khaki*, had to depend on white pith helmets to protect them from sunstroke, for sometimes the temperature rose to one hundred and twenty degrees and at all times the Indian sun at midday is dangerous. But without intermission, except when the monsoon blew, (as it did at times with force enough to whip the canvas awning off the crane and send it swirling over the bent tree tops down the gorge) or when in the rainy season the whole sky emptied itself into the valleys, the bridge was pushed forward. No heat daunted

the men, and in the rainy season, from July to October, the rain had a comfortable habit of falling mostly at night. * * * * * *

By November 1, 1900, the viaduct was completed. The last rivet was driven; the last coat of steel gray paint was put on; the natives were paid off and sent away with the usual *chit* or recommendation; the big traveler was removed, and the Americans were sent home. The ground was cleared up, the track was laid across the viaduct, and the long steel structure was ready for the tests of the railway company. The tests lasted two months. Heavily laden trains were run over the viaduct, and expert engineers examined every detail. After the most thorough scrutiny the railway accepted it, expressing complete satisfaction, and the Secretary of Public Works offered the congratulations of the Government of India on the successful completion of the undertaking.

The railroad from Rangoon to Gôkteik was of metre-gauge, and the largest freight cars were capable of carrying only nineteen tons, while some of them had a capacity of only six tons. Some of the pieces shipped up from the sea were 55 feet long, and had to be hauled up the fifteen mile *ghât* below Thondaung, on which the grade was one in twenty-five and the curves as sharp as nineteen degrees. The viaduct was officially opened on the first of June, 1901, by His Excellency Sir Frederic Fryer, K. C. S. I., Lieutenant-Governor of Burma, and the leading Government and railway officials."

THE GOKTEIK VIADUCT, BURMA

Reprinted from "Engineering Record," January 12, 1901

The Gôkteik viaduct, which has attracted probably equal attention on both sides of the Atlantic, was, it is hardly necessary to say, built and erected by The Pennsylvania Steel Company under the direction of Mr. J. V. W. Reynders, superintendent of the bridge and construction department, for the Burma Railways Company, Limited, Messrs. Sir Alexander Rendel & Co., London, Consulting Engineers. The structure is part of a new railroad line from Mandalay to Kunlon on the Chinese frontier, and is located at a point about 2,135 feet above sea level and about 400 miles from the seaport city of Rangoon. It crosses a deep and wide valley and is built on top of a high transverse bank forming a natural bridge several hundred feet above the stream in the bottom of the valley. The top of this bridge is, however, over 300 feet below the grade of the railroad crossing the valley, and there remained above it a chasm which has been spanned by a steel structure 2,260 feet long and 320 feet in maximum height, dimensions which place it in the front rank among the Kinzua, Pecos and other great viaducts.

The general designs were approved by the consulting engineers, who sent a resident engineer to the bridge works at Steelton, Pa., while the plans, details and shop work were being executed. A very liberal spirit was manifested in this supervision of design and work, which were both conformable in general to American practice, although some special features introduced in accordance with English methods are exceptional here. For example, all the members of the 120-foot lattice girder trusses were assembled together and reamed in the shops and then disconnected for separate shipment, as were the different sections of the column lines. The contract was considered notable as being the

first one let by English parties to a foreign firm at a total pound price for the building and erection of an important colonial structure complete, the general custom being to not include the erection in the contract for the structure.

The viaduct was designed to carry two railroad tracks and to have a footwalk for pedestrians. The towers are finished complete for this service, but the roadway and floor system is only constructed for one track and the footwalk at present, provision being made to add the necessary girders and trusses for the second track at some future time.

The combined dead and live load from the train, girders, etc., for each 1-meter track, which is carried on one trestle bent, was assumed at 387,000 pounds, and a wind pressure was assumed of 33.6 pounds per square foot on a continuous train surface 11 feet high and on both sides of the structure. This gives a maximum upward reaction at the foot of one column of 667,000 pounds, corresponding to 682,000 pounds in the inclined column. At the allowed working stress of 12,000 pounds per square inch, this is provided for by a rectangular cross-section made up of one 22 x $\frac{9}{16}$-inch cover plate, two 18 x ¾-inch web plates, two 3½ x 3½ x $\frac{9}{16}$-inch angles and two 3½ x 3½ x ⅝-inch angles.

The viaduct consists of fourteen 30-foot single towers and one 60-foot double tower with ten 120-foot lattice girder connecting spans and seven 60-foot plate girder connecting spans, two of which are supported at their adjacent ends on a short rocker bent. Each single tower has four columns battered 5:24 in two vertical transverse bents. It is divided into equal vertical stories of about 35 feet each, with longitudinal and transverse struts at every story and stiff X-bracing in every panel of all four faces of the tower. In all bents the members are alike and are interchangeable in corresponding stories from the top downward, except in the bottom stories, which are specially fitted to the irregular ground surface. The centers of the columns of every tower are 40 feet apart longitudinally and 24½

feet apart transversely at the top, and in the tallest bent, which has nine stories, they are 156.4 feet apart transversely at the bottom. Each tower has horizontal diagonal bracing in every alternate story from the top down. Below the third story from the top, the middle points of the transverse struts are supported by a vertical intermediate column, and below the sixth story these struts are supported again at their quarter points by vertical members which, at the sixth story, are suspenders from the intersection of diagonals above, and below that are struts from the ground. At the highest part of the viaduct there is a double tower, 80 feet long, which has three transverse bents, and is braced in every panel of all faces like the single towers. In each bent the tops of the columns are connected by a double web box plate girder, 60 inches deep, which has the longitudinal girders and trusses seated on its top chord. Every member of the tower bracing has a latticed, rectangular or I-shaped cross-section made up of four angles, and is field-rivetted to pairs of $\frac{7}{16}$-inch gusset plates at the ends and intersections.

For 281 feet at one end and 341 feet at the other end the axis of the viaduct is curved to a radius of 800 feet. The intermediate 1,638 feet is a tangent, and its height varies from 130 and 213 feet at the two ends to 320 feet at the three-bent tower. Eventually there will be four lines of main longitudinal girders, one pair for each track, but at present there are only enough girders provided to carry one track and to support refuge platforms for pedestrians at every tower. There are three longitudinal girders at the top of each tower, one of the center girders there and one pair of connecting girders between adjacent towers being omitted. The 40 and the 60-foot spans are plate girders respectively $42\frac{1}{2}$ and $60\frac{1}{4}$ inches deep, and the 120-foot spans are single triangulation lattice girder trusses with the centers of the top chord panels supported by vertical struts from the bottom chord panel points. The chords are made in single panel lengths, and all members are field rivetted

at connections. At the level of the lower flanges of the top chords of the lattice girders, the whole structure is decked with continuous flat steel plates $\frac{5}{16}$-inch thick. Between towers the space 11 feet wide between the centers of the connecting girders is decked with similar plates supported by the main girders, and on the top flanges of two lines of track stringers and the floor beams, which are $13\frac{1}{2}$ feet apart.

The total shipping weight of the viaduct was 9,760,000 pounds, distributed as follows: Plate girders, 1,860,000 pounds; lattice girders, 1,320,000 pounds; columns and bracing, 6,580,000 pounds. Nominally the shipping lengths were restricted as nearly as possible to a maximum of 30 feet, but much longer pieces, up to nearly 60 feet, were sent without much difficulty and arrived in good condition, few or none being loaded on deck. To facilitate the classification and separation of members and handling them by ignorant foreign labor, a very comprehensive color system was applied in painting them at the shops, which embraced all the principal colors and various combinations of them, stripes, etc. The erection traveler was painted black, each truss, girder, column, etc., was painted a distinctive color, and the joints of the columns when shop-assembled were each painted with a special combination of stripes on each adjacent piece. This system made the different pieces conspicuous whenever they were visible at all in a pile, and made their identification by the key easy for the erector.

The equipment sent out with the men and materials comprised erection plant and tools, various supplies in stock and duplicates of small parts of the mechanical apparatus liable to wear, breakage or loss. There was a steam-driven air compressor and pneumatic reamers and rivetting hammers, three four-spool hoisting engines, two guyed derricks, two stiff-leg derricks with rigging complete, the usual complement of hand tools and other items of an erection outfit, with liberal supplies for possible losses

and a stock of tool steel from which the toolmaker and smith were able to make all special appliances required at the site. There was also a complete photographic outfit, a medicine chest and a telephone system which was established at the site to communicate between different parts of the viaduct and the shops, office and storage yard. An elaborate cable code was devised in which there was a word for every member of the viaduct and of the erection plant, words to signify that the erection and rivetting of the structure had been completed to successive points, and words to convey any necessary messages concerning each member of the American party. Progress reports were cabled home every week at a tariff of $1.25 a word.

All material was delivered at grade at one end of the viaduct and was handled in the storage yard there by steam derricks. A low-level service track was built on timber trestles across the deepest part of the valley, and materials were lowered to it on an inclined plane and delivered for the lower parts of the tall towers. All other materials were run out on top of the finished structure and through the traveler and lowered to place as required. The erection was accomplished by a traveler 24½ feet wide, 60 feet high and 219 feet long on centres, which had an unprecedented overhang of about 165 feet total length. It was built entirely of steel with pin-connected trusses, weighed 180,000 pounds, and was sold for scrap after the erection was completed. The rear end was counterweighted and anchored to the viaduct and had clearance over the track to receive the viaduct members, which were delivered from the storage yard on small cars. They were transferred to tackles suspended from a trolley, which ran on the lower chords of the overhanging trusses and was pulled out to the required position by the hoisting engine, which also lowered the members and held them until assembled and connected so as to be self-sustaining. Most of the rivetting was done by the natives, who worked well and cheaply, and so large a force of them were employed in five-men gangs that

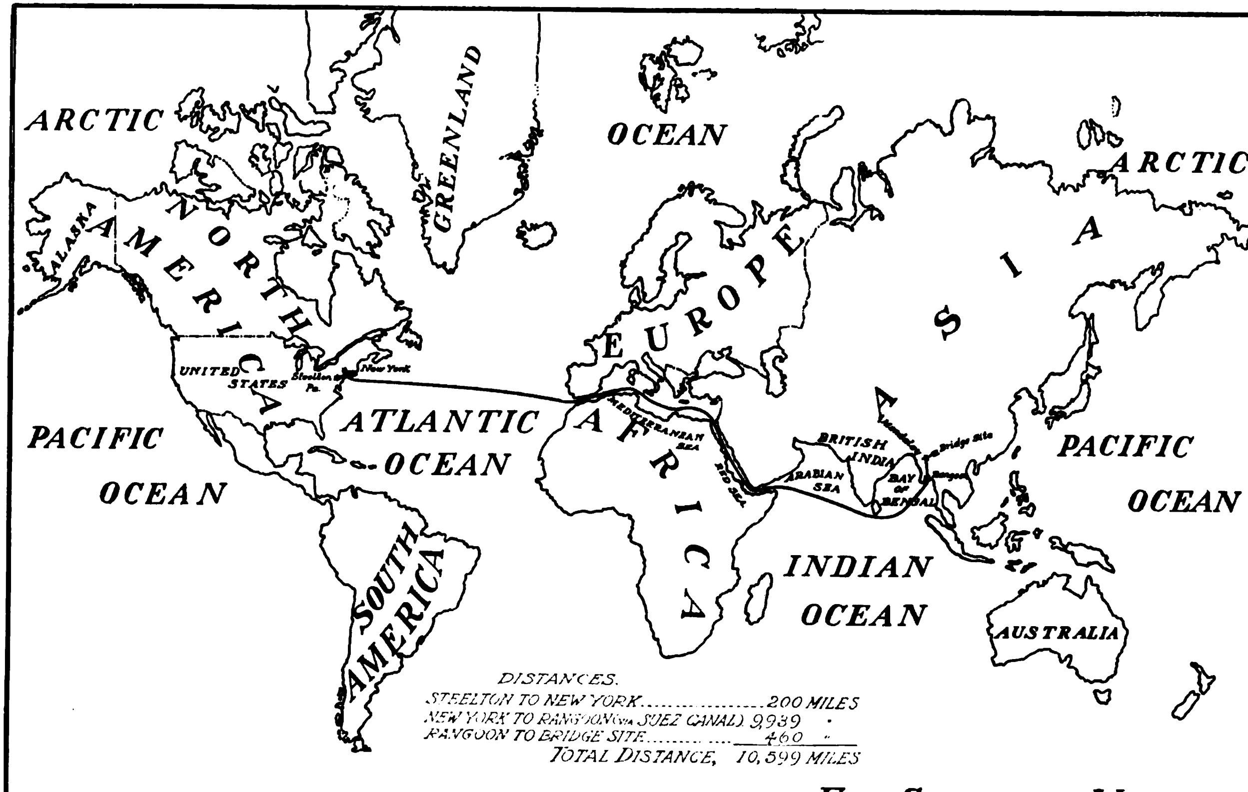
they kept well up with the assembling. There were in all about 200,000 field rivets driven, chiefly ⅞-inch except the ⅝-inch ones in the floor plates and some 1-inch ones in the girders.

The material was shipped from New York direct to Rangoon, on three steamers which sailed in August, October and November, 1899, and arrived out about two months later. Both materials and freight bills were fully insured. From Rangoon to the bridge site the steel was shipped in narrow-gauge cars over a road which, beyond Mandalay, was newly constructed and had many four per cent. grades over which the effective train load was only about 80 tons, equivalent to two car loads from the Steelton shop. The material that arrived in November had to wait till the middle of January for the road to be completed to the bridge site, because its construction had been greatly retarded by unprecedented rains and washouts in the preceding October. Two parties of thirty-five men in all were sent from the shops in October, 1899, and in February, 1900, via Suez Canal, and made the trips going and coming in from six to eight weeks. Houses were built and a mess established for these men, and the erection was commenced in January, 1900, and finished in October.

A maximum force of about five hundred natives was employed and paid about $17 a month each, a price much in advance of local wages. They came from Lahore and the Punjab and largely from Calcutta, and included many seamen. Some of them had worked on the railroads and were tolerable mechanics. Coolies were employed for simple labor. Work was carried on during the rainy season from May till September, when there was no continuous rain, but heavy showers were of daily occurrence, and most of the annual precipitation of 150 to 200 inches occurred. The temperature in these months seldom rose above 75 degrees, and most of the remainder of the year was very pleasant. As long as the men abstained from intoxicants they had no sickness, but as soon as they indulged in liquor its effect was immediately noticed in fevers and similar diseases, from which one man died. No

other casualty occurred, and there was no serious accident to either Americans or natives, a remarkably fortunate record considering the nature, conditions and magnitude of the work and the large number of unskilled men employed in dangerous places.

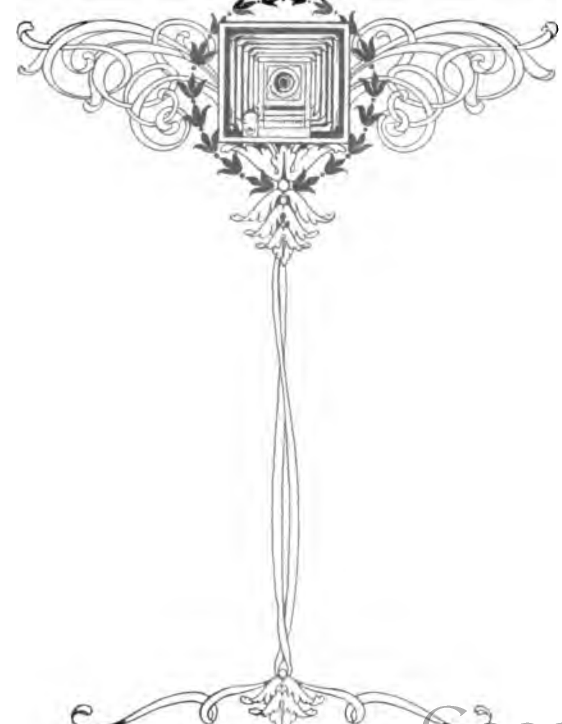
The officials in Burma were Mr. A. T. Goodfellow, General Agent for the Burma Railways Company, Limited; Mr. G. Deuchars, Chief Engineer for construction, and Mr. J. H. White, Resident Engineer. Messrs. Sir Alexander Rendel & Company, London, Consulting Engineers, were represented in America by Mr. W. H. Clark. The structure was designed, manufactured and erected by The Pennsylvania Steel Company under the direction of Mr. J. V. W. Reynders, Superintendent of the Bridge and Construction Department.



FROM STEELTON TO MANDALAY.

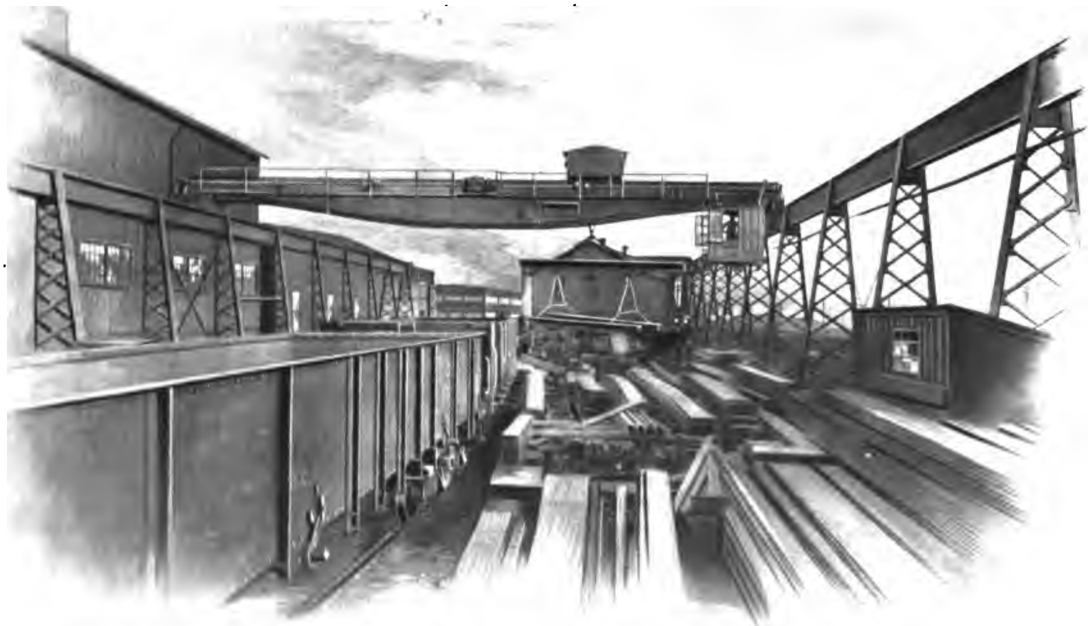
FROM STEELTON TO MANDALAY:

AS RECORDED BY THE CAMERA



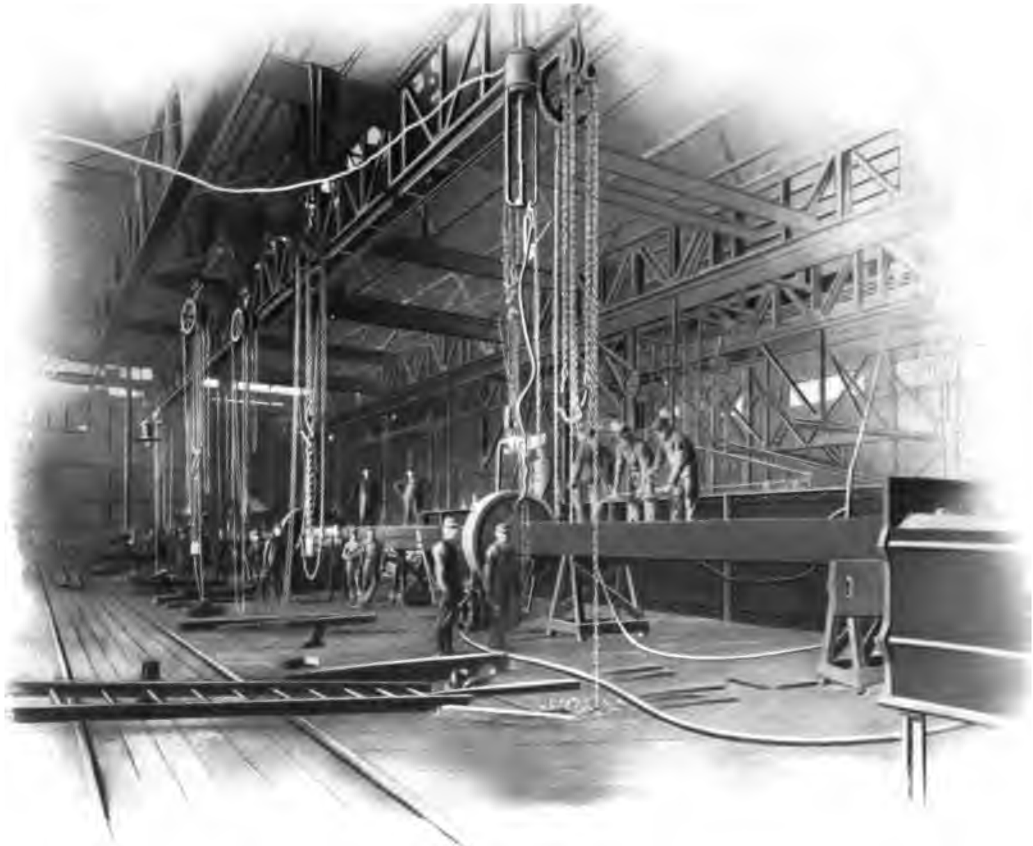
From ore to pig iron. A group of blast furnaces at Steelton

Manufacturing steel
in the open hearth
furnaces



Electric crane
unloading steel
at the bridge
works

Assembling and reaming departments, bridge works



Scene in the
rivetting depart-
ment of the
old works

A solid train-load of viaduct material leaving Steelton 31st July, 1899. 43 cars containing 977 tons

S. S. Bucentaur taking aboard first consignment of 1,693 tons, New York, 31st August, 1899

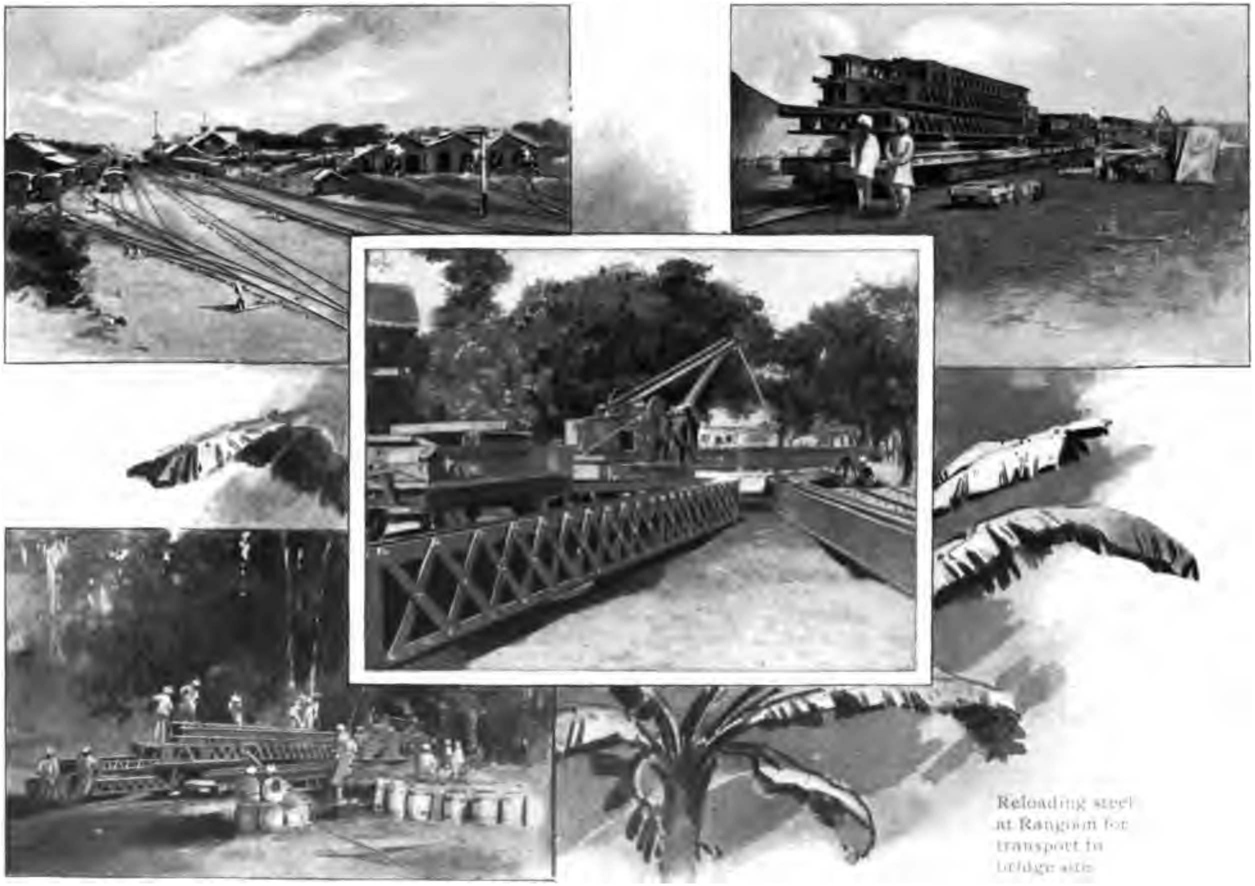
Views of the docks at Rangoon, Burma, where the steel was unloaded, showing shear legs and landing stage

Some of the American erectors and their Indian interpreters

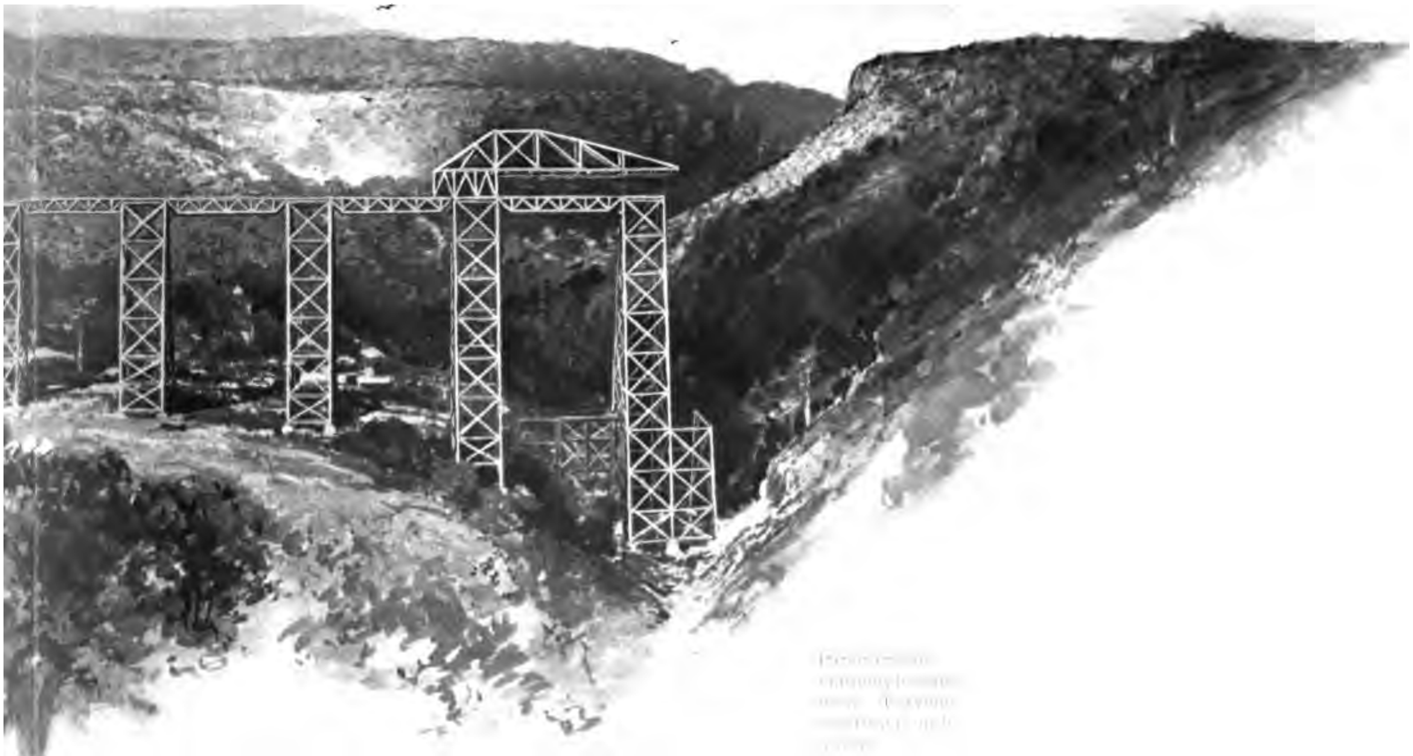
Dalhousie Park,
Rangoon. Shway
Dagobn in distance

Shway Dagohn
(golden pagoda)
at Rangoon

Steel stored on
the wharf
at Rangoon,
March, 1900.



Reloading steel at Rangoon for transport to bridge site






Transporting steel
from Rangoon to
Gökteik Gorge

Panorama of
Mandalay,
showing the palace

The yards near
bridge head, where
material was stored
and classified

Final assembling and rivetting of 120-foot spans on **completed viaduct approach**

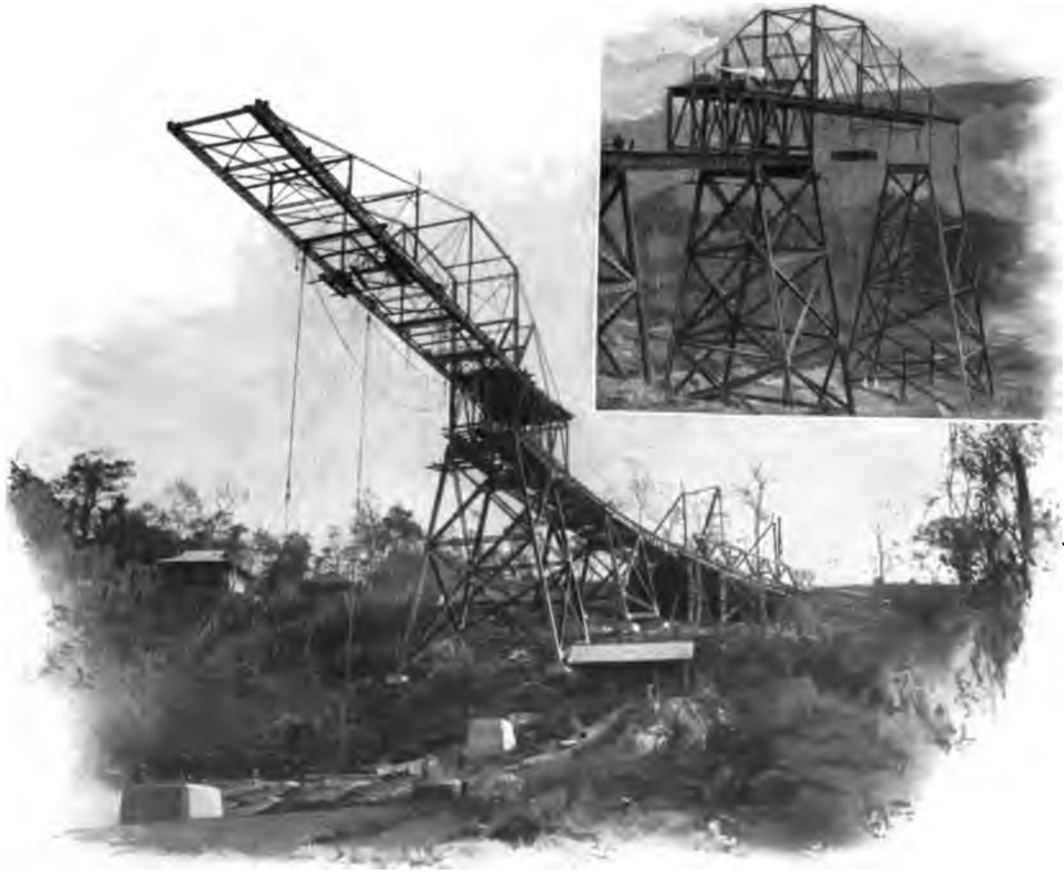
Steam hoisting engines manned by Americans

Native workmen and their quarters

Bungalows
occupied by railway
officials, steel
company's foreman
and resident
engineer. Also
quarters of
American workmen

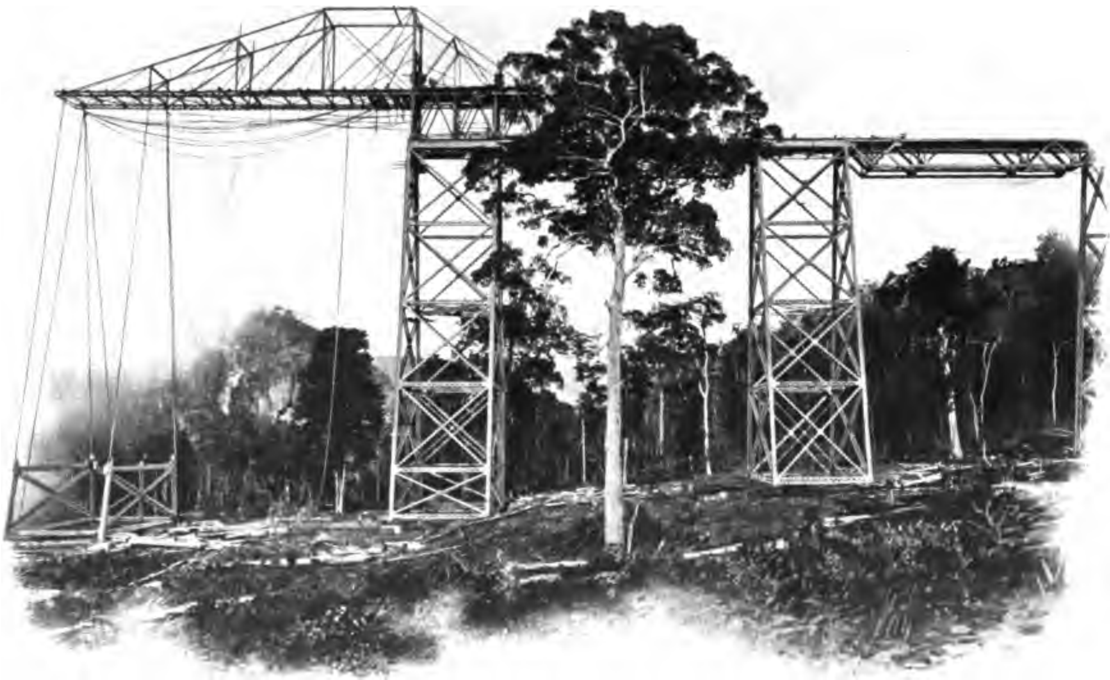
Group of native
foremen (maestris)
and interpreters.

Progress of erecting
steel traveler,
7th February, 1900

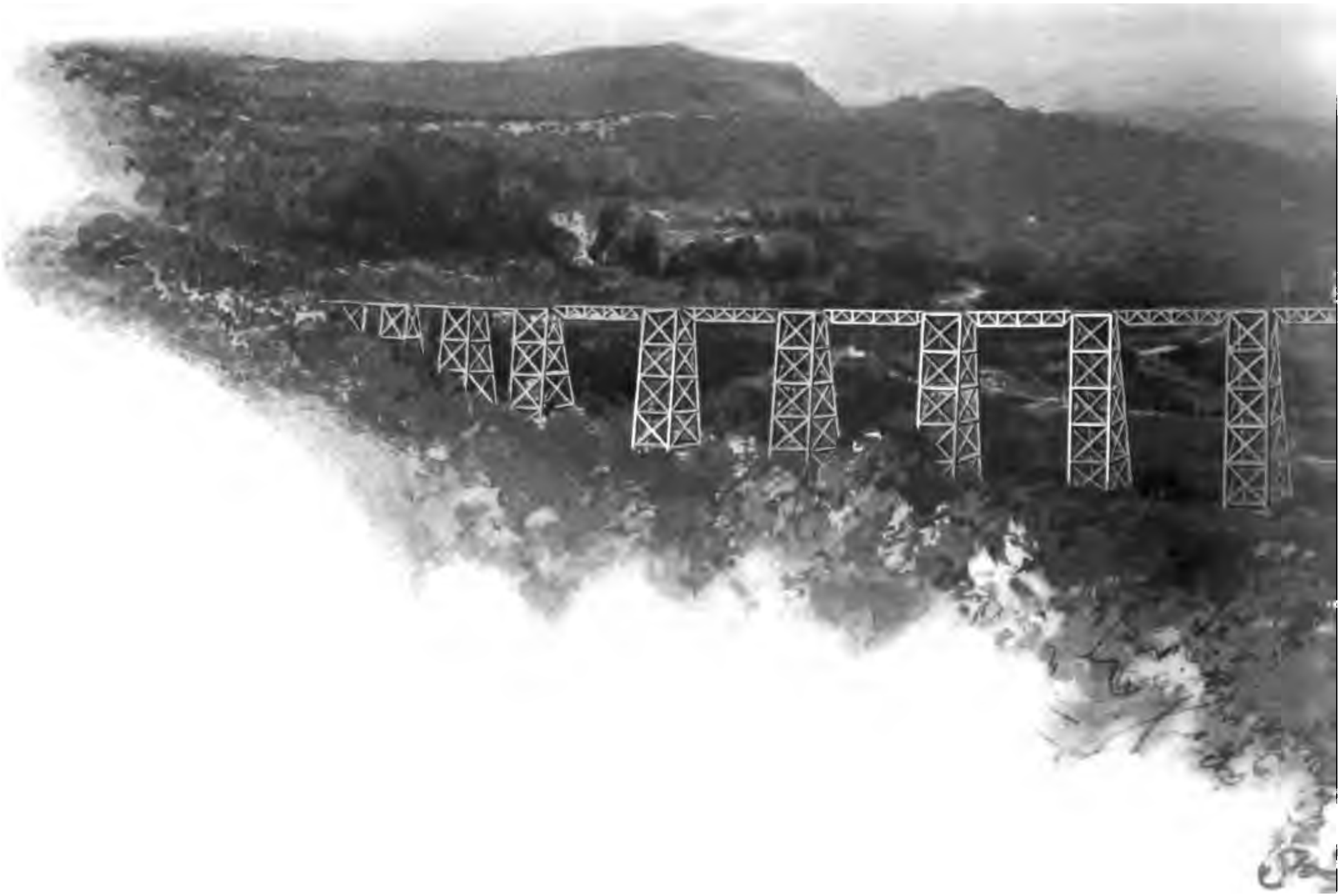


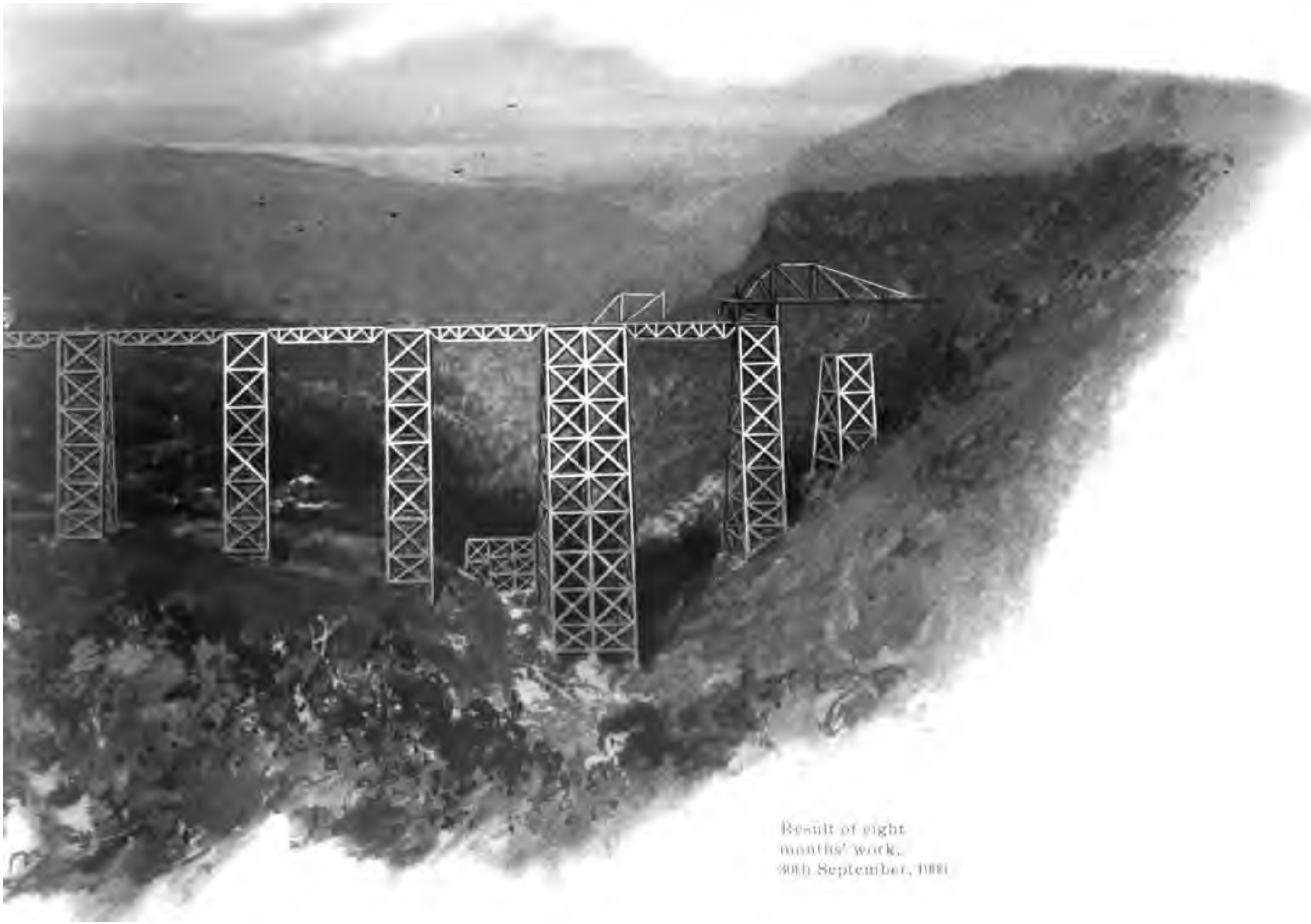
Traveler transporting box girder forming support for spans

Steel traveler ready for operation 23d February, 1900

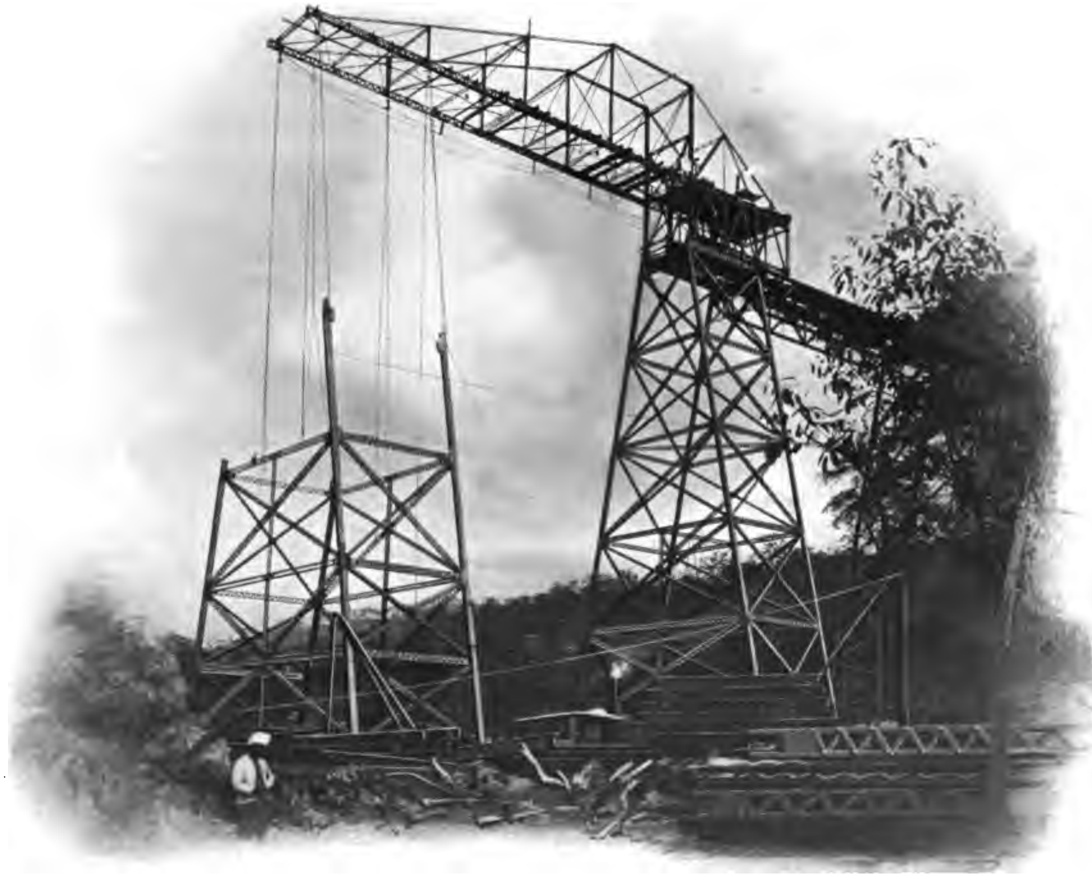


Starting work on a
small tower
12th May, 1900

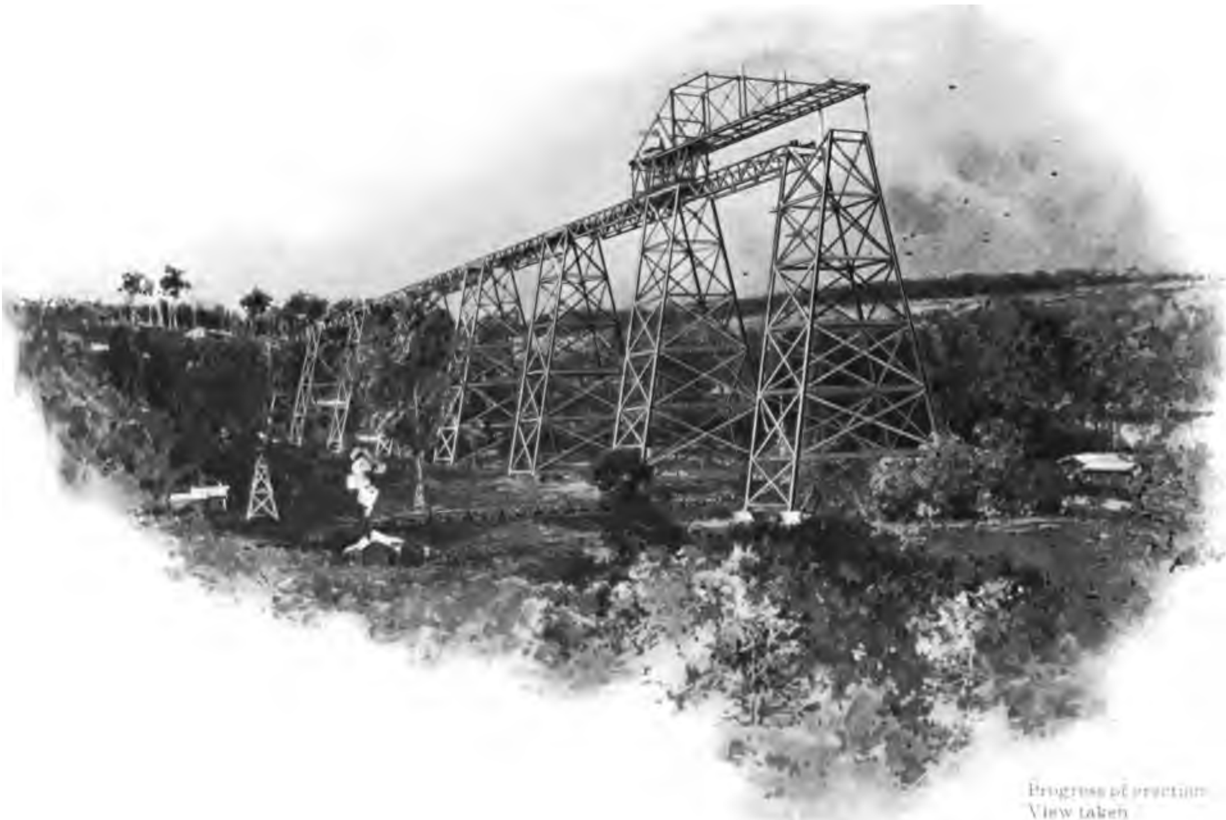




Result of eight
months' work.
30th September, 1900



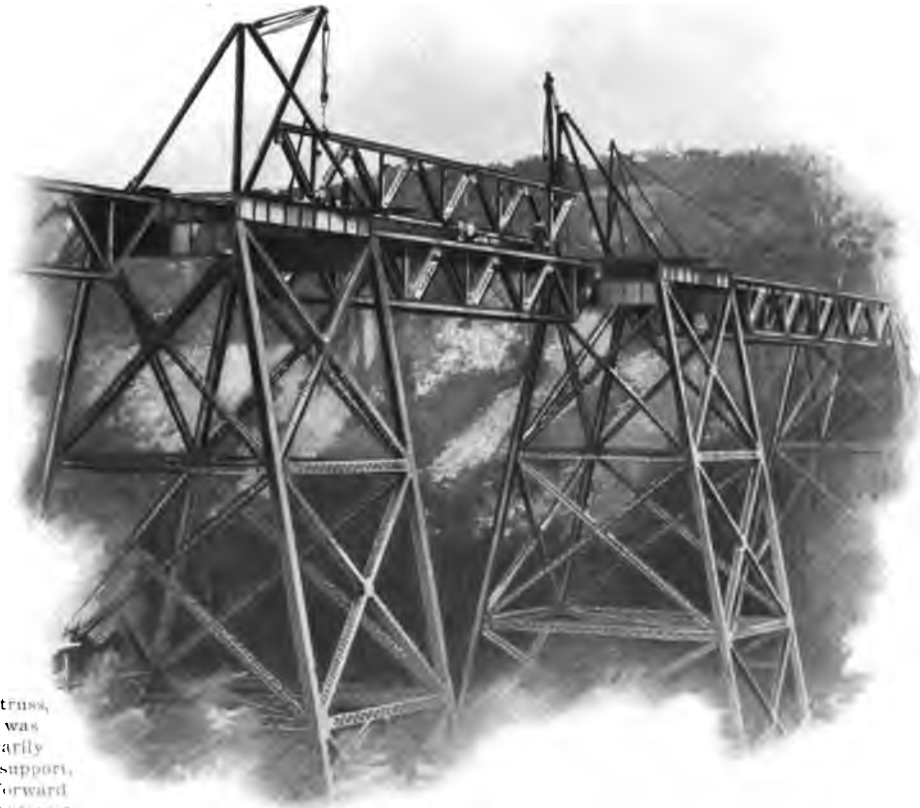
Progress of erection
View taken
5th June, 1900



Progress of erection
View taken
30th June, 1900

Natives delivering half-truss to traveler on completed portion of viaduct. Traveler placing truss in position

One of the 120-foot
lattice trusses,
12 feet deep and
weighing 26 tons



A duplicate truss, here shown, was used temporarily for traveler support, and moved forward from tower to tower as the work progressed

The natural bridge
on which the tower
foundations rest

Natives rivetting

Returning from work

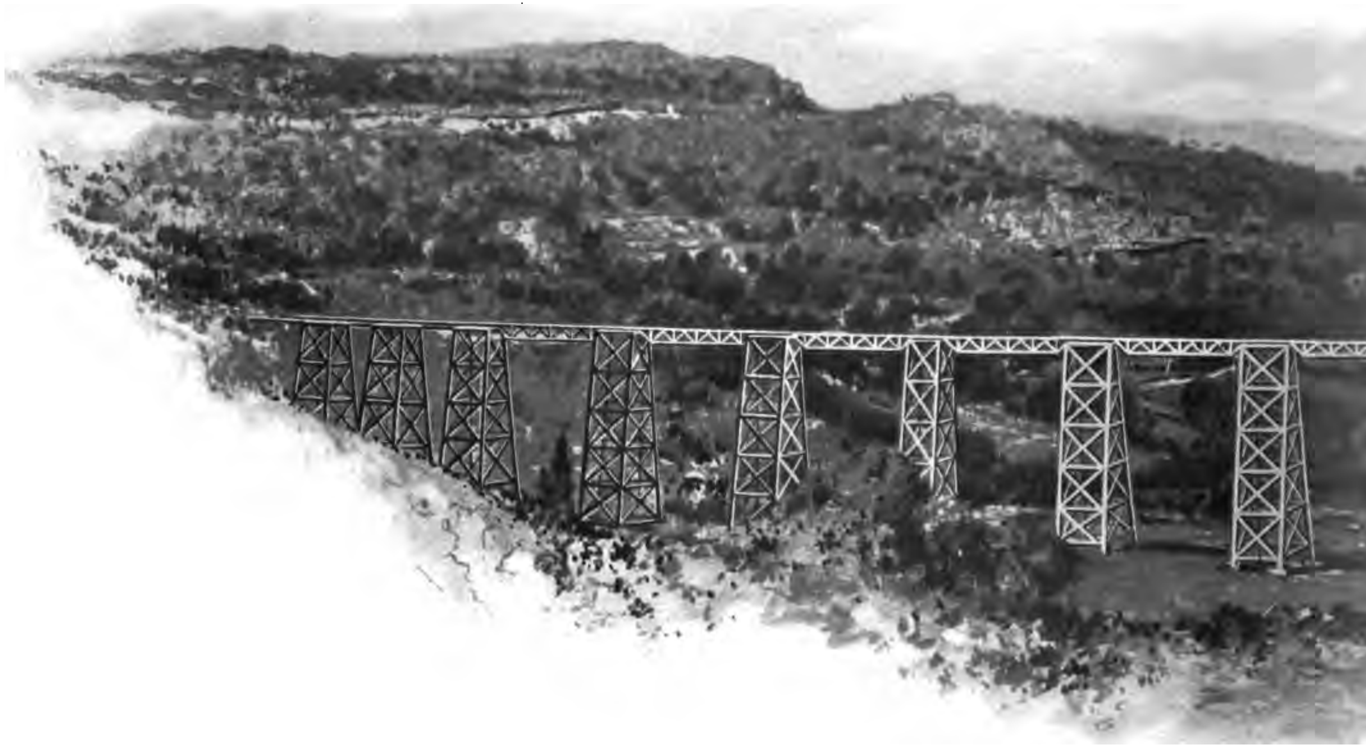
Natives of many types

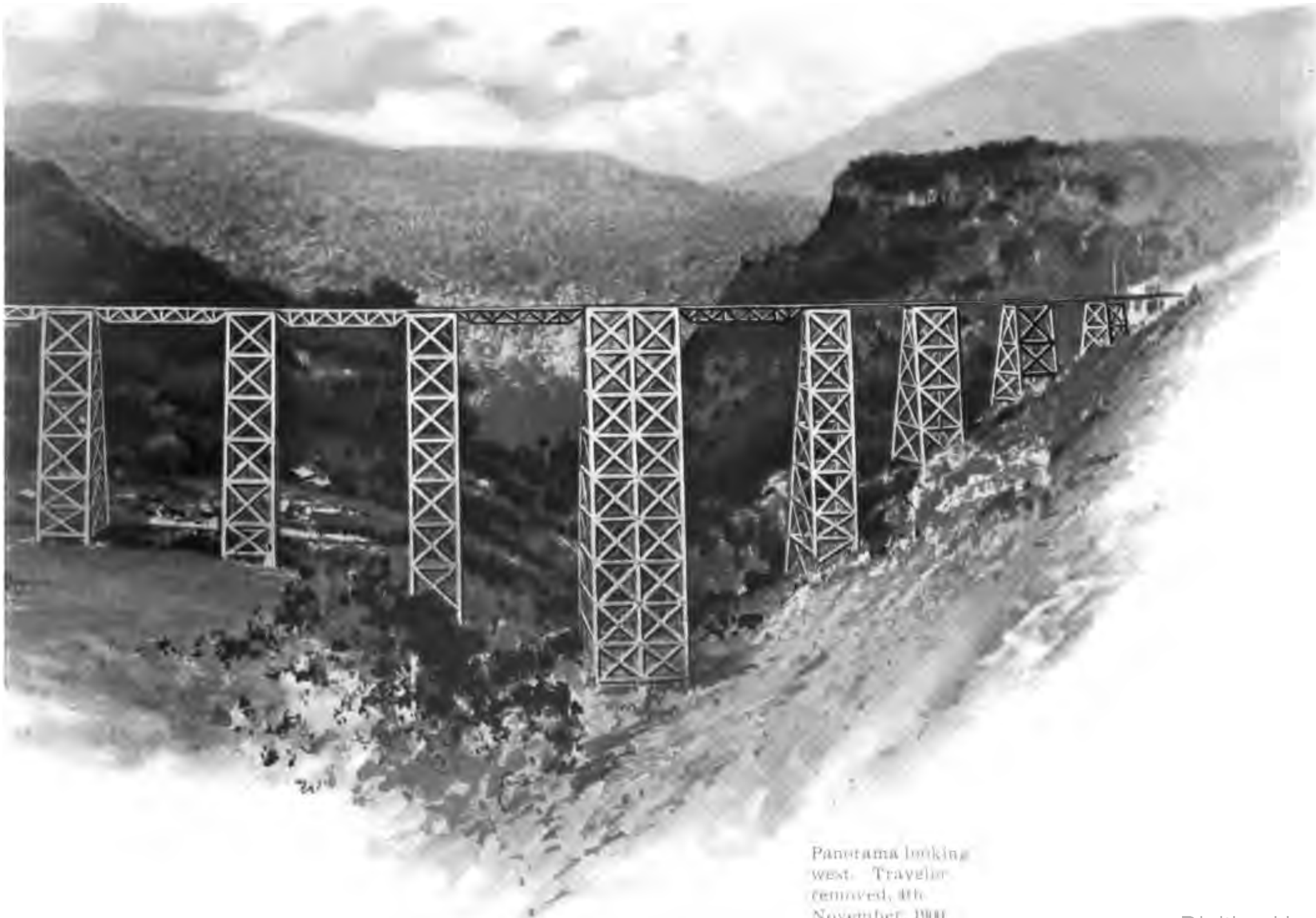
Where Americans were needed

Where the Chungzoune disappears from view, 825 feet below the railway tracks

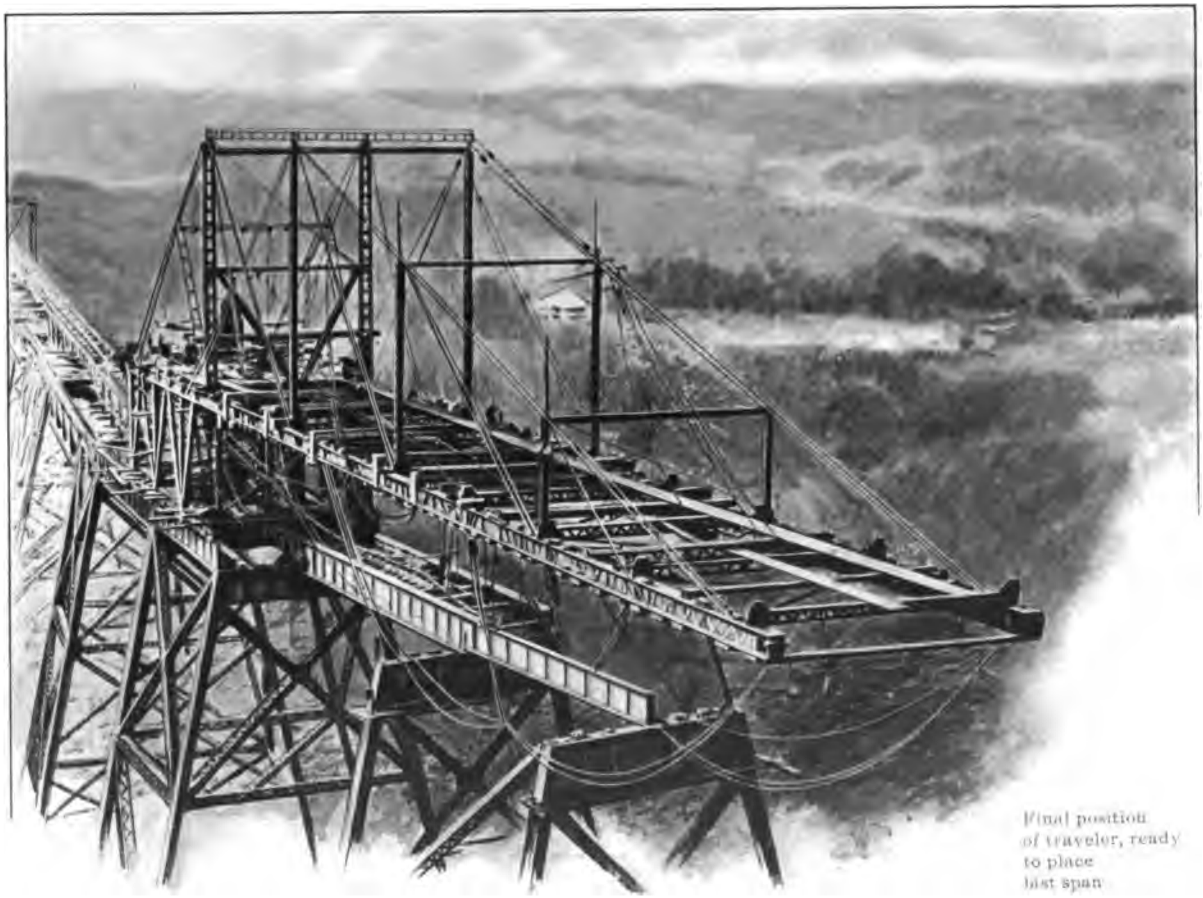
Nearing the finish,
9th September, 1900

View of extreme
end of traveler





Panorama looking west. Traveler removed, 4th November, 1900



Final position
of traveler, ready
to place
last span

Longitudinal bracing at foot of towers

Where many forces meet

Column base, showing connection of transverse bracing

Details of the 120-foot lattice truss

One of our visitors—the Sawbwa of Thibaw, with his wives and suite

Birdseye view of
bridge and gorge

Railway deck,
showing refuge
platforms for
pedestrians

The highest tower
taller than a
"skyscraper"

The completed
viaduct looking
south

American locomotives on an American bridge

THE Pennsylvania Steel Company owns and operates works at Steelton, Pennsylvania, Sparrows Point, Maryland (near Baltimore), and additional blast furnaces at Lebanon, Pennsylvania. The company also controls ore mines in Cuba and at Cornwall, Pennsylvania, and operates the Cornwall and Lebanon Railroad.

PRODUCTS

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Rails for Steam and Electric Service
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Pig Iron, Slabs, Blooms and Billets
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Spring Steel, Special Steels
Steel Castings, Forgings

FROM MARYLAND WORKS

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FROM LEBANON WORKS

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American foreman

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